Next steps with IBS suppression lattice

Mei Bai, Dmitry Bruno, Peter Cameron, Roger Connolly, John Cupolo, Al Della Penna, Alexei Fedotov, George Ganetis, Vladimir Litvinenko, Yun Luo, Nikolay Malitsky, Aljosa Marusic, Christoph Montag, **Vadim Ptitsyn**, **Todd Satogata**, **Steve Tepikian**, Nick Tsoupas

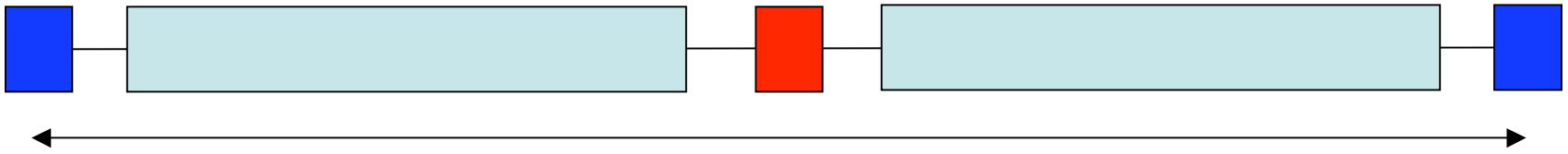
Content

- **Reminder: what is IBS suppression lattice?**
- Where we are?
- Potential gains from IBS suppression lattice
- What are next steps?
- Conclusions

Transverse IBS in RHIC

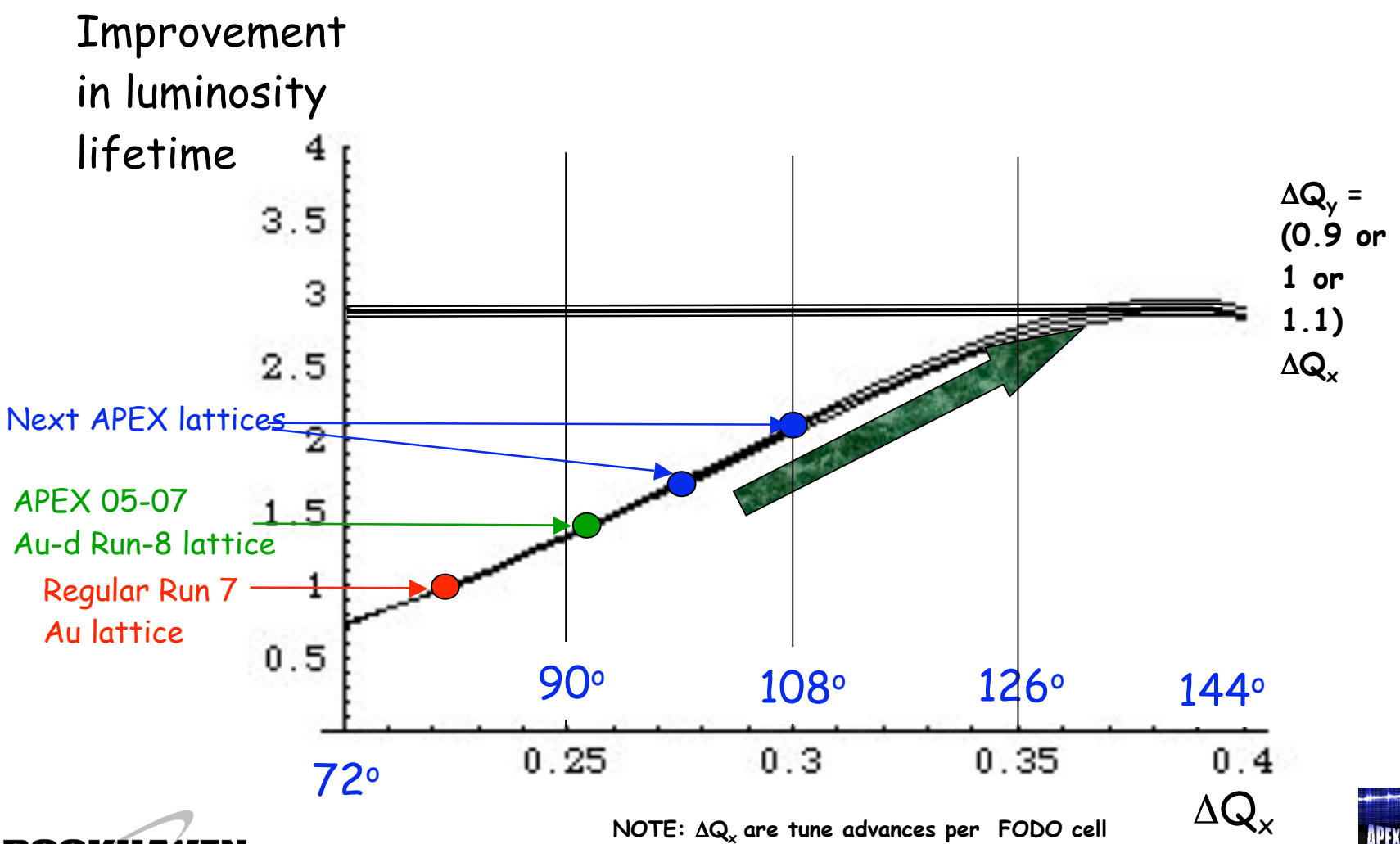
The main contribution to the transverse IBS in RHIC come from the arcs, most of which comprised of FODO cells

$$\frac{d\varepsilon_x}{ds} = H(s)\cdot\frac{d\delta_E{}^2}{ds}; \qquad H(s) = \gamma_x D_x^2 + 2\alpha_x D_x D_x{}' + \beta_x D_x{}'^2$$



$$\frac{d\delta_E{}^2}{ds} \propto \frac{N}{\sigma_s \sigma_r{}^2 \sigma_{r'}}; \qquad H_{\mathrm{mod}}(s) = \frac{H(s)}{\sqrt{\beta_y(1+\alpha_x{}^2)+\beta_x(1+\alpha_y{}^2)}}$$

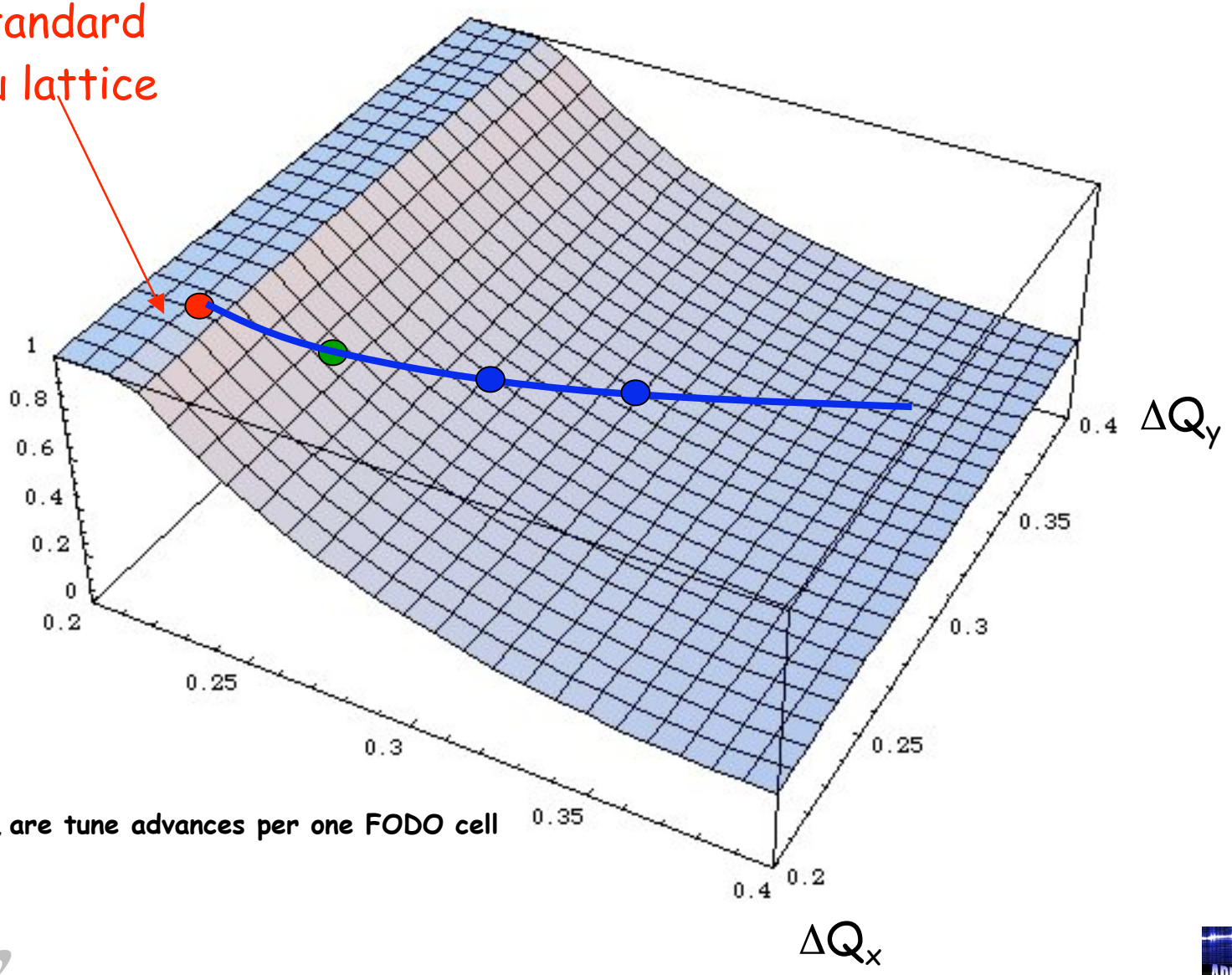
Reduction of the IBS rate, i.e. increase of the luminosity lifetime



NOTE: ΔQ_x are tune advances per FODO cell

Relative transverse IBS rate in RHIC

Standard
Au lattice



NOTE: $\Delta Q_{x,y}$ are tune advances per one FODO cell

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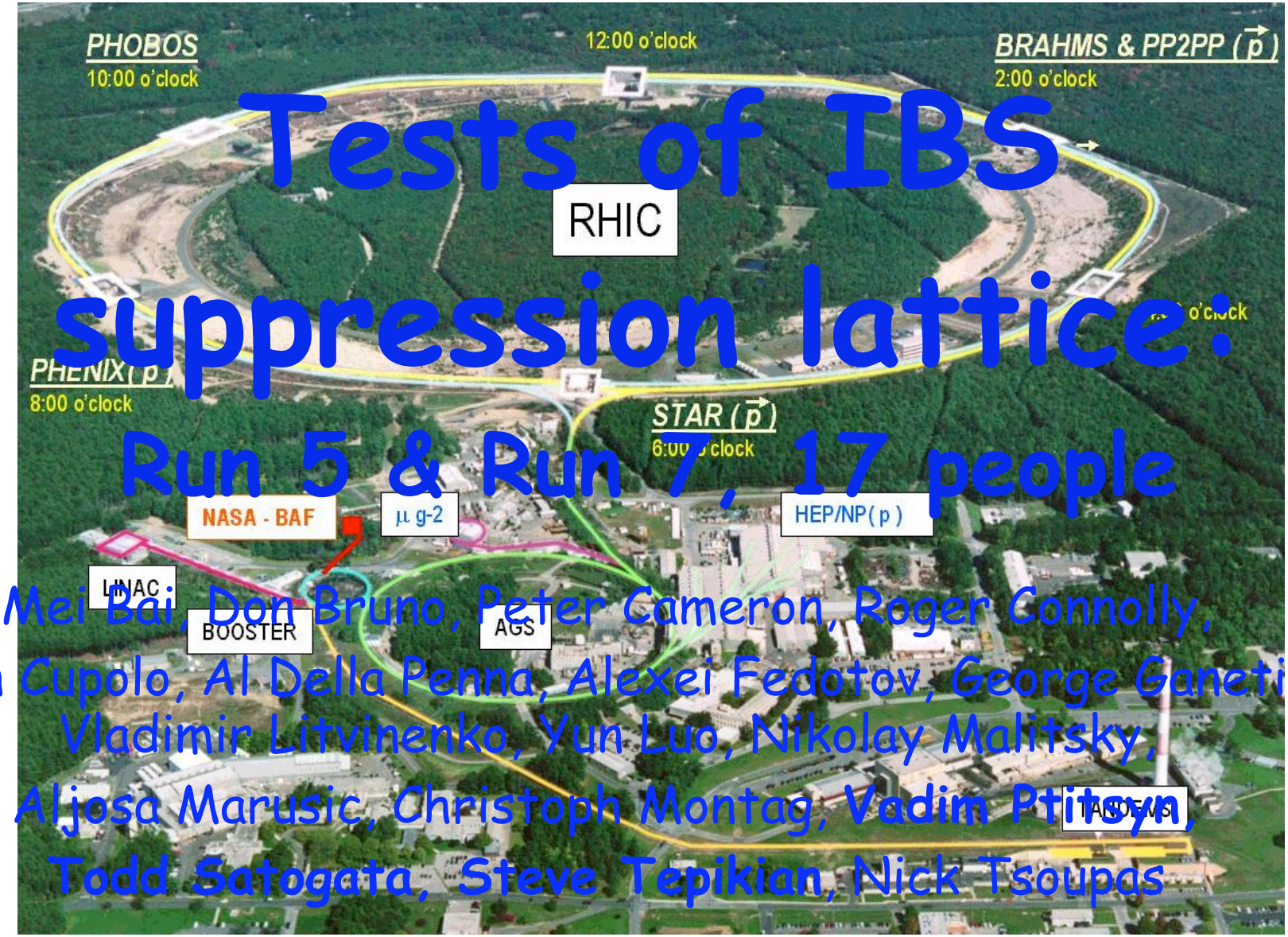
Tests of IBS suppression lattice: Run 5 & Run 7, 17 people



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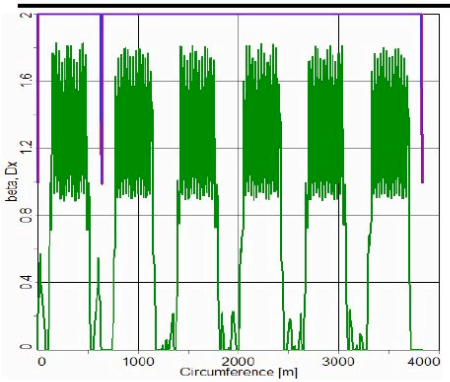
Cu101 Ramp: Problems with qf/d6

IBS Lattice Development

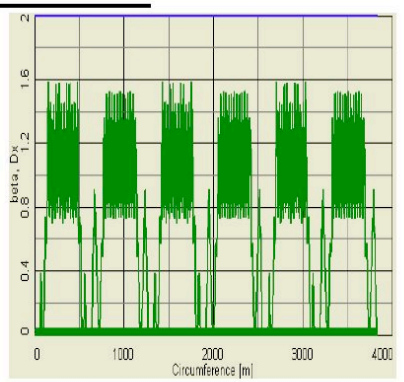
S. Tepikian

- Raise the tune
  - Increases the cell phase advance
- Optics must work within existing power supplies
- Selected $\beta^* = 3m$
  - Enough aperture for beam at injection
  - Goal: $\alpha_1 = -1.5$ implying: γ_T transparent
    - Didn't turn out this way
- Ramp to different energies
  - Cu101: 100GeV; Cu102: 85GeV and Cu103: 31GeV

RHIC-4 lattice vs 92 degree phase advance

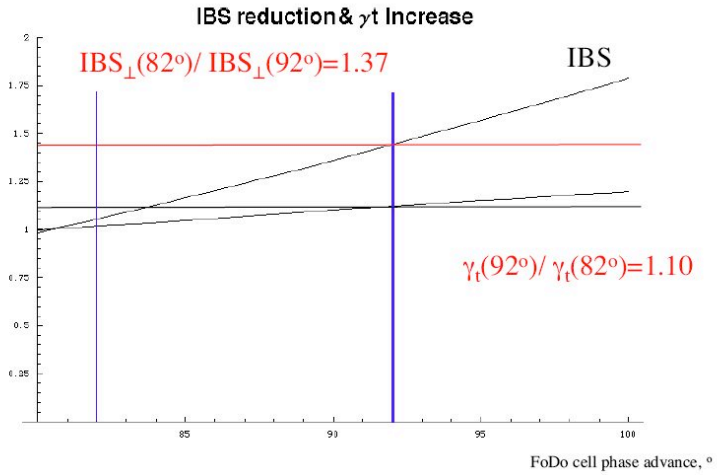


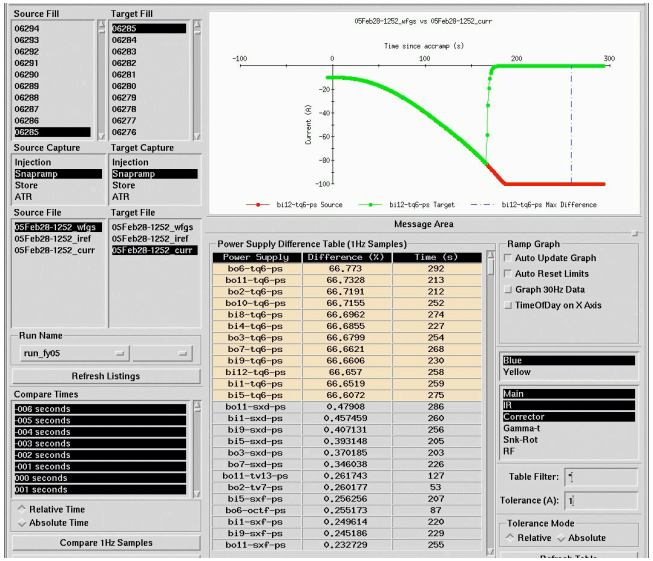
RHIC-4 dispersion



92 deg. phase advance

Reduction of the IBS rate

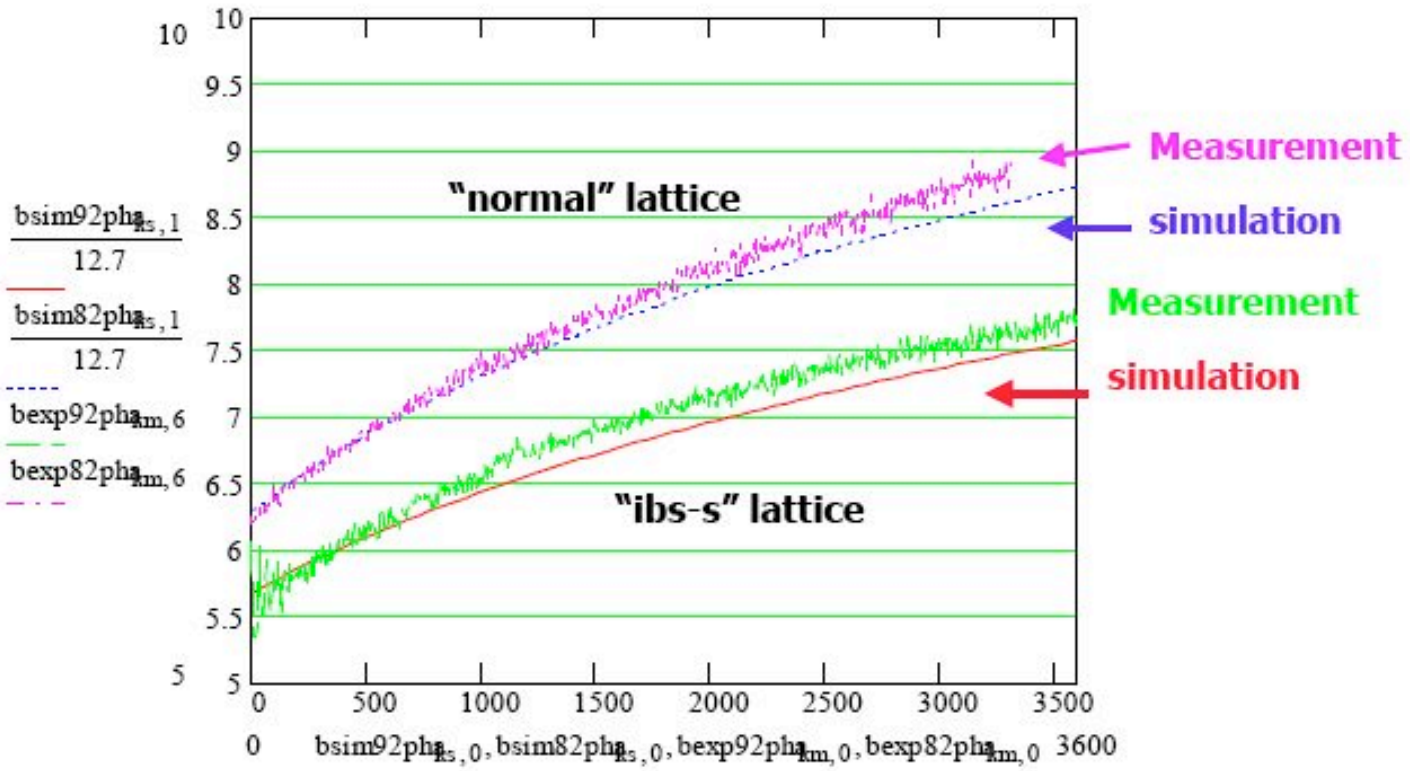




During all ramps, tq6 power supplies still consistently tripped -> 31 GeV test

IBS Lattice Development

A. Fedotov



Run-7 - IBS suppressed

Long story full of surprises (perfect tune feed-back ramp in blue followed by problem with SC splice….)

Final test

Blue with standard lattice

Yellow with IBS suppression lattice

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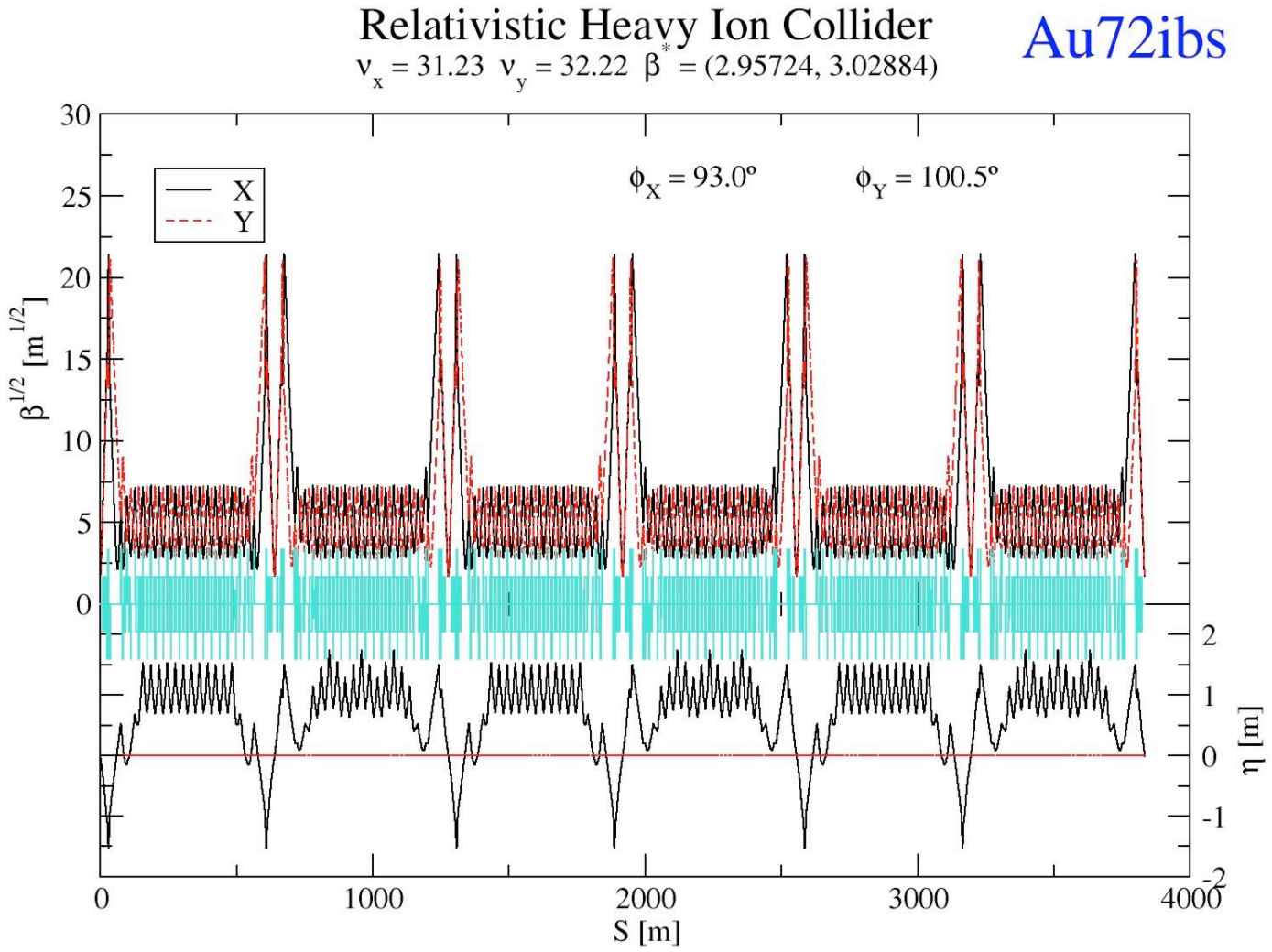
Au72ibs - Run 7



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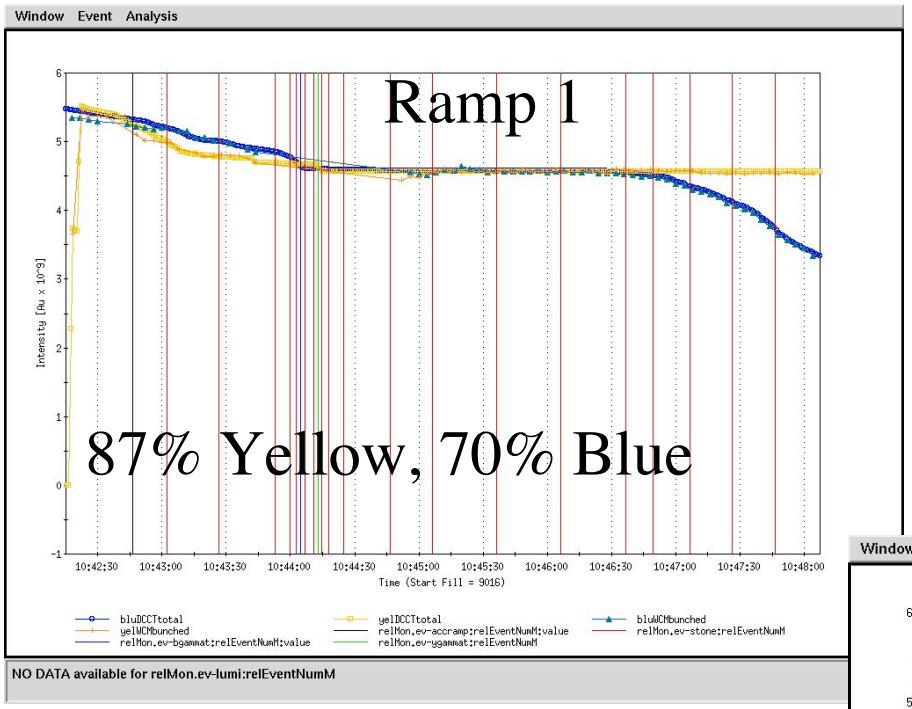
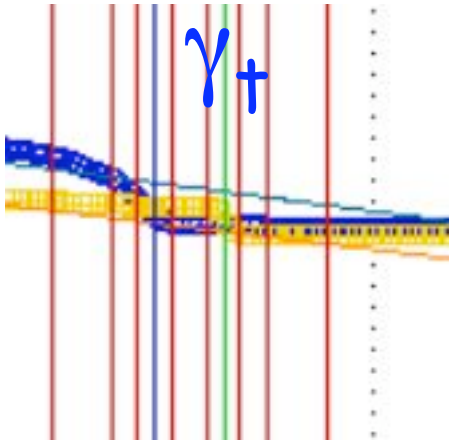
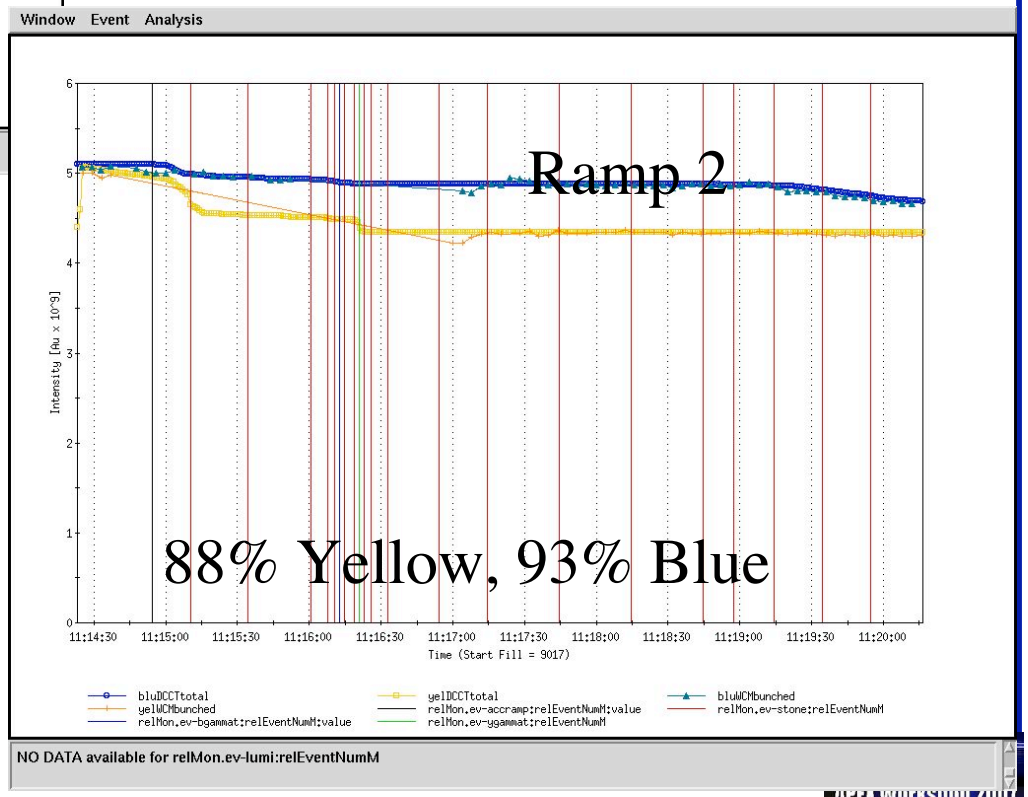






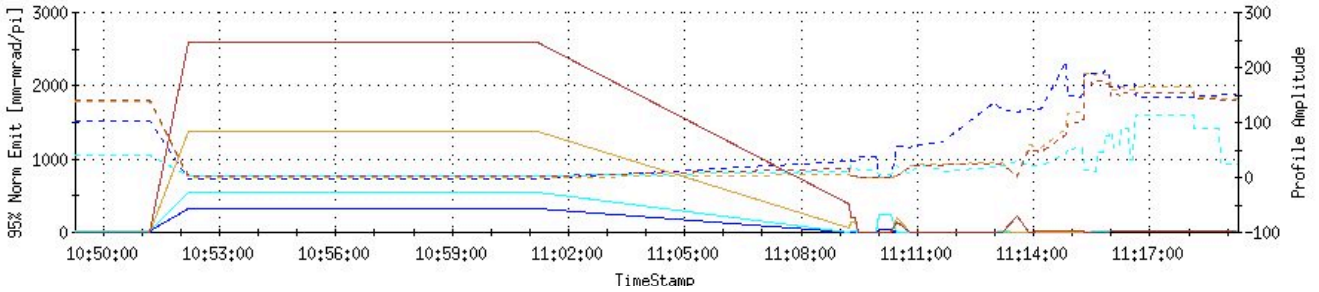
6 bunches per ring:
3 bunches ~ 1e9 Au
3 bunches ~ 5e8 Au

Rhic Ionization Profile Monitor

View Setup Help

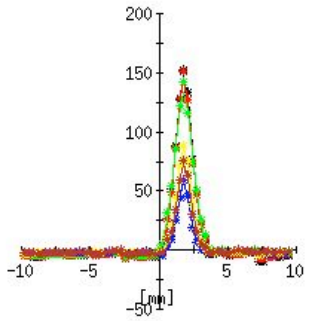
Function	Horizontal	Vertical	Horizontal	Vertical
Time-stamp	Jun 20, 11:19:14	Jun 20, 11:19:16	Jun 20, 11:19:16	Jun 20, 11:19:14
Bucket	1	1	1	1
Norm-Emit [pi*mm-mrad]	12.887	11.5293	10.8554	10.9763
Sigma [mm]	0.625493	1.37467	0.536585	1.73854
Intensity	505.396	48.6008	457.617	901.664
More Info	More...	More...	More...	More...

95% Normalized Emittance [mm-mrad/pi] and Profile Amplitude

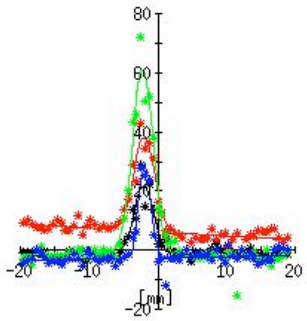


Vertical IPM in blue was noisy

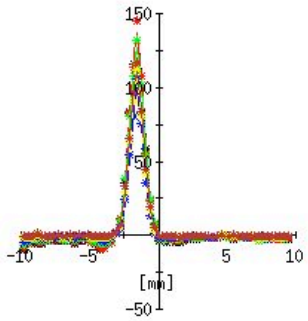
Blue_Horizontal



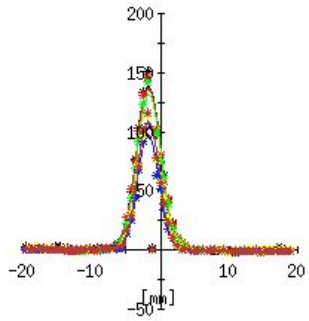
Blue_Vertical

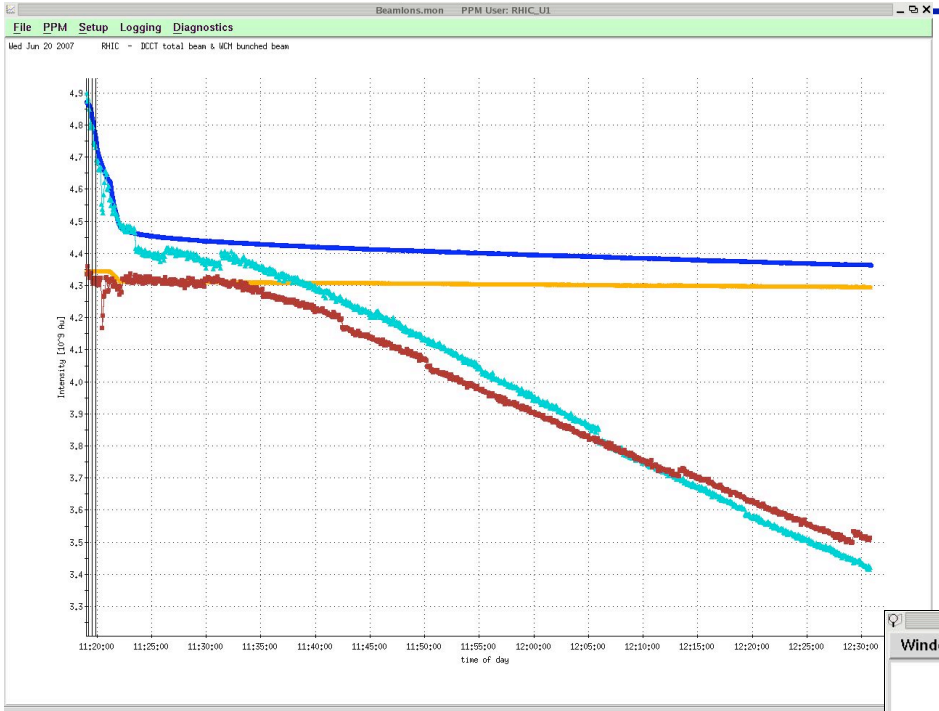


Yellow_Horizontal

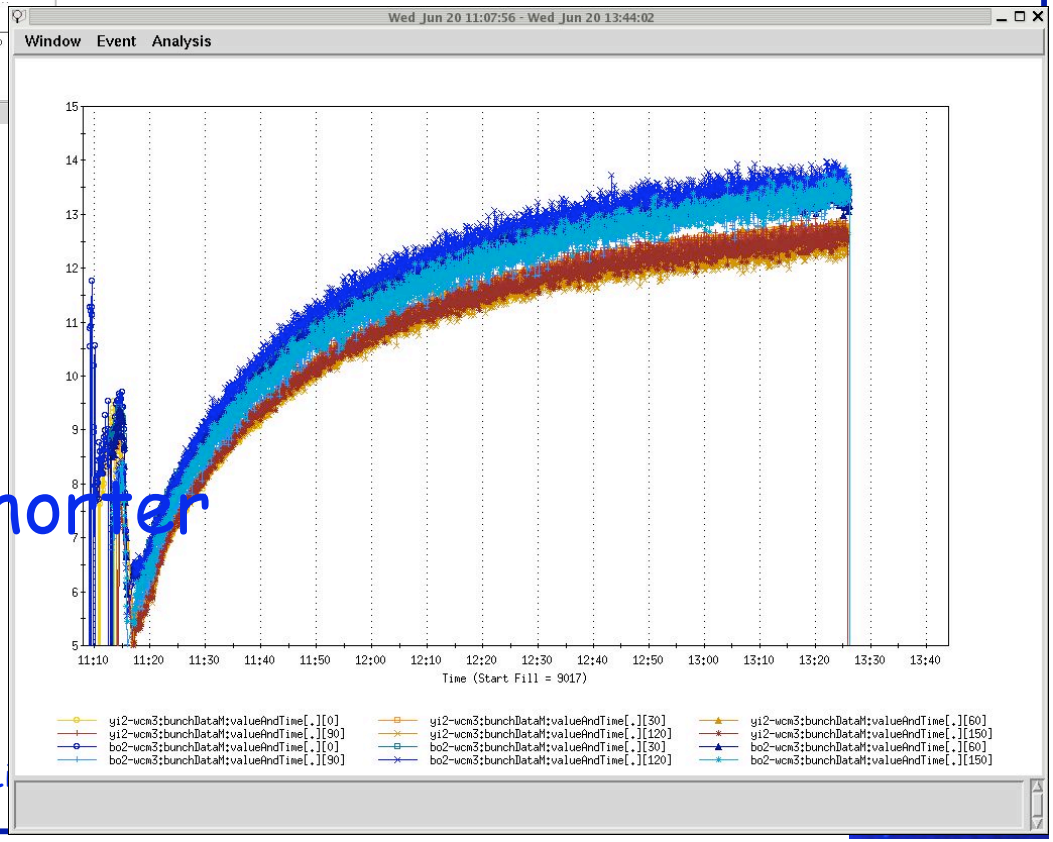


Yellow_Vertical

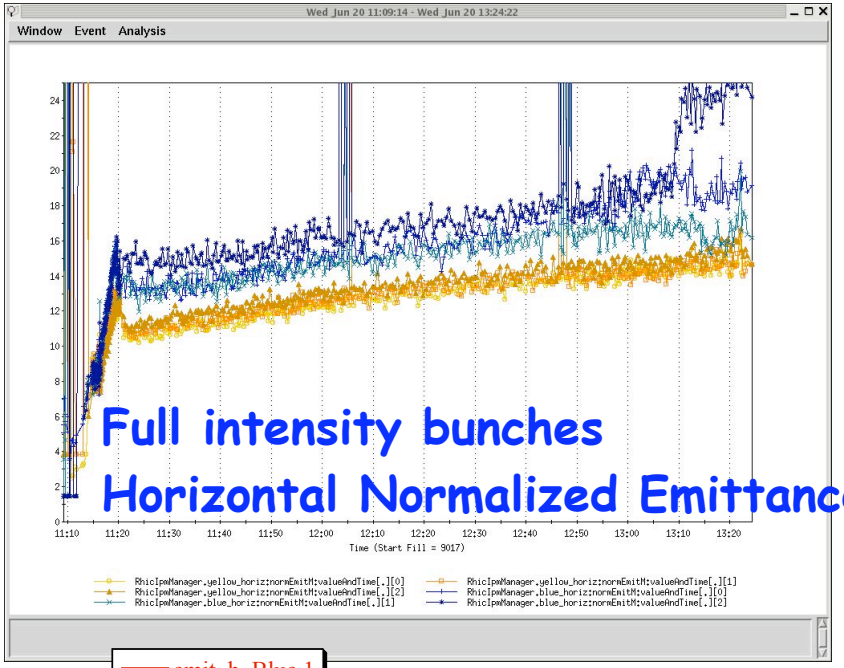




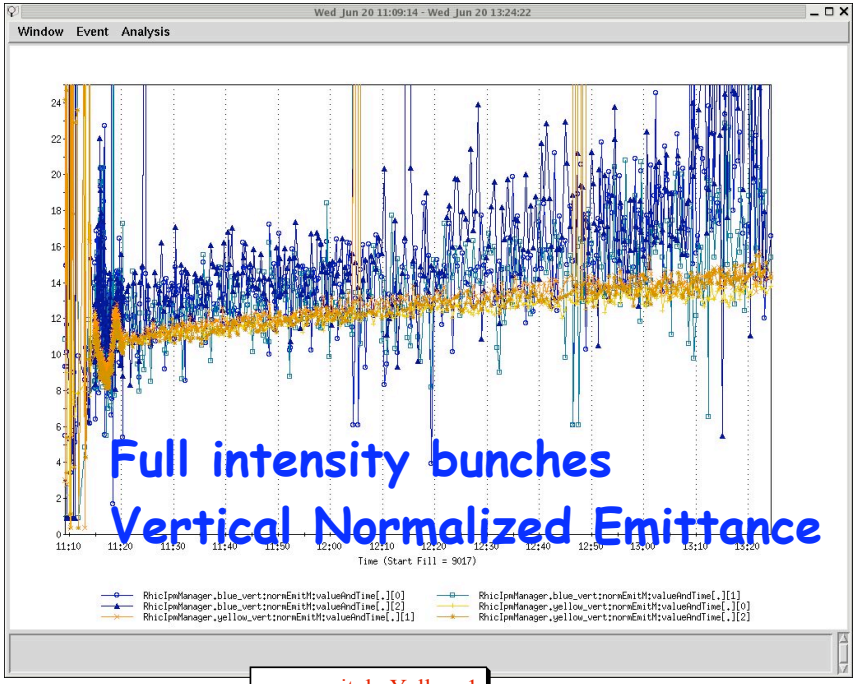
De-bunching:
Yellow is slightly better



Bunch lengths :
Yellow bunches are shorter
And stay shorter

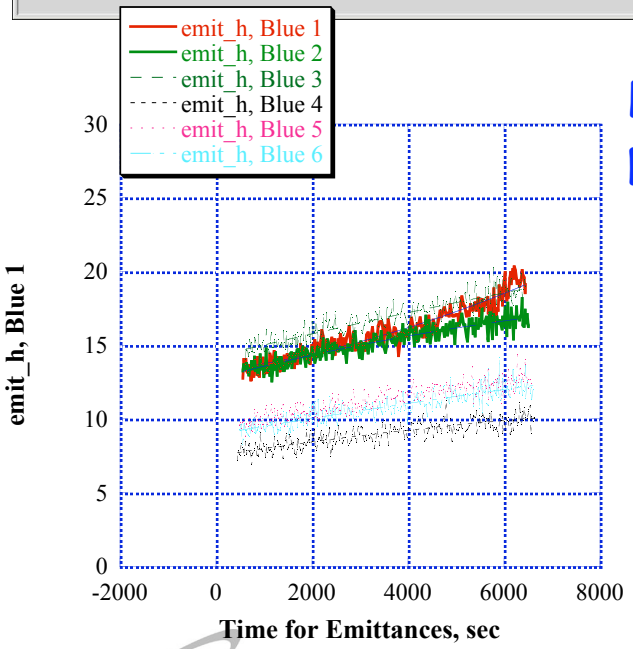


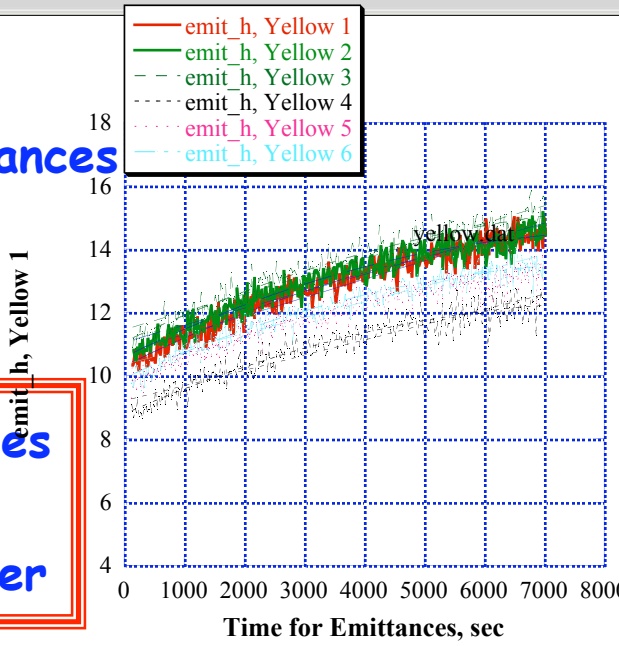
Full intensity bunches
Horizontal Normalized Emittance



Full intensity bunches
Vertical Normalized Emittance

Horizontal Normalized Emittances





Yellow emittances
are smaller
and stays smaller

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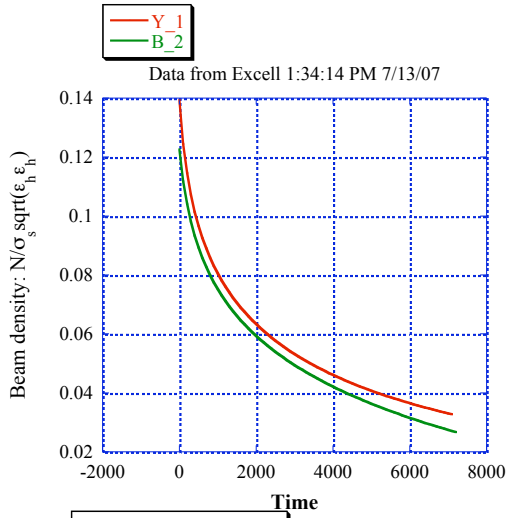
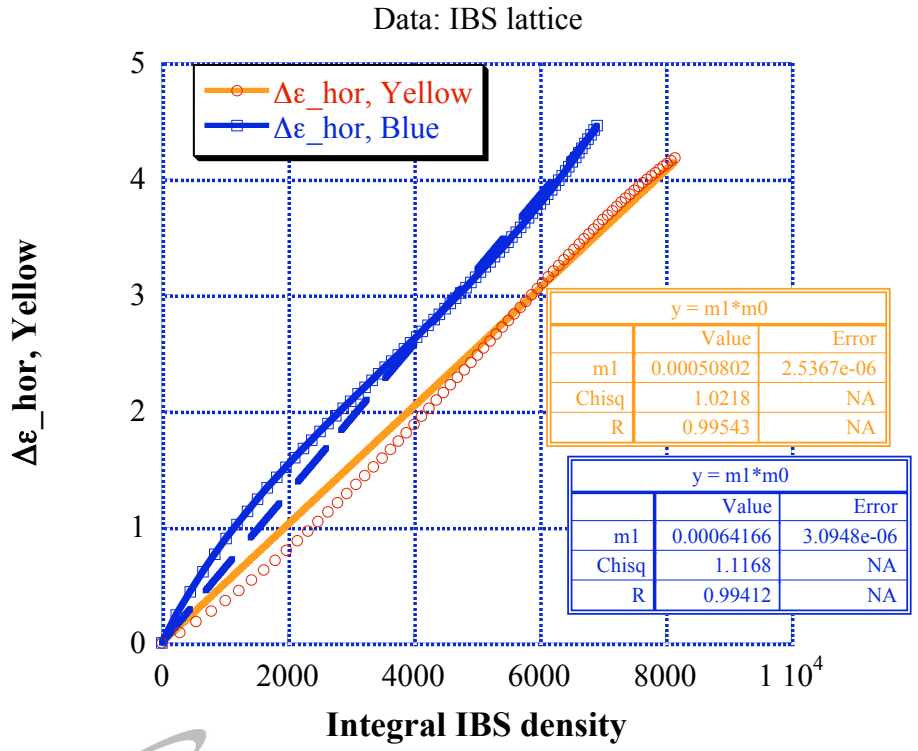
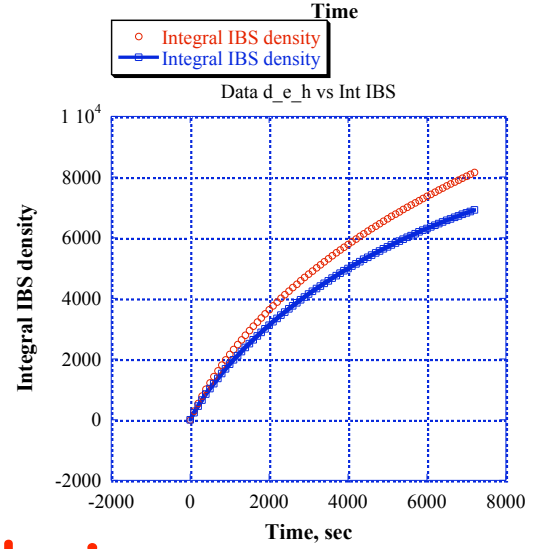
IBS suppression lattice experiment

$$IBS\ \ Integral\ (t) = \int_{o}^{t} \frac{N(t')dt'}{\sigma_z \sqrt{\varepsilon_h \varepsilon_v (\varepsilon_h + \varepsilon_v)}}$$

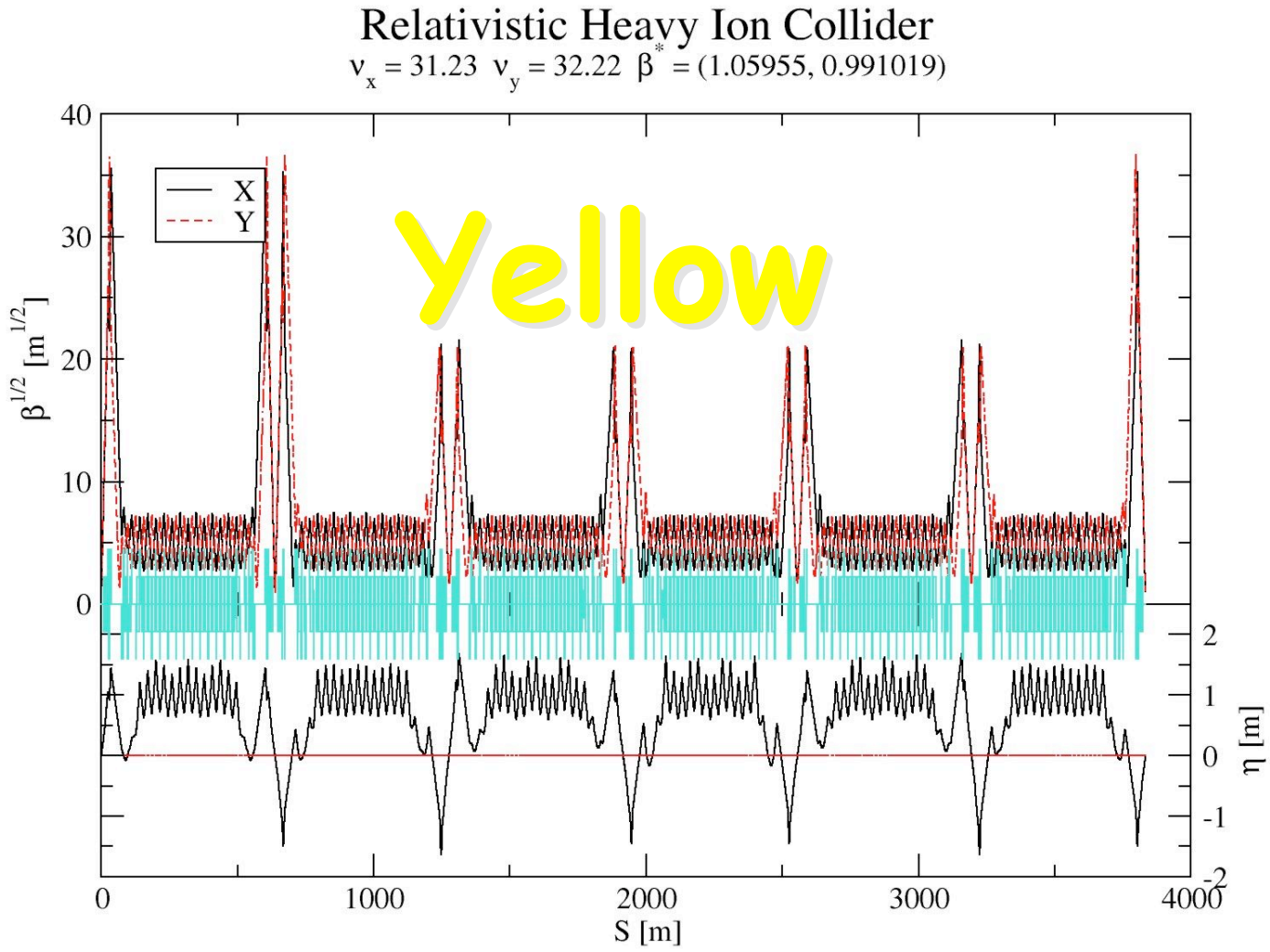






- **Conclusions**
  - Transverse IBS is suppressed by 30±10%

dAu80 lattice - Run 8



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Conclusions I

- IBS suppression lattice has advantages in all three degrees of freedoms
  - Emittances are lower and grow slowly (note that IBS ~ $1/\varepsilon^{3/2}$)
  - Bunch length is shorter and de-bunching is lower (consequence of stronger focusing, i.e. higher γ_t -> large energy acceptance, shorter bunches) - well matched with stochastic cooling
  - Blue has a mechanical problem which should be fixed for future runs, Yellow works fine with IBS lattice
  - In d-Au we will have longer luminosity lifetime and gains in average and vertex luminosity

Content

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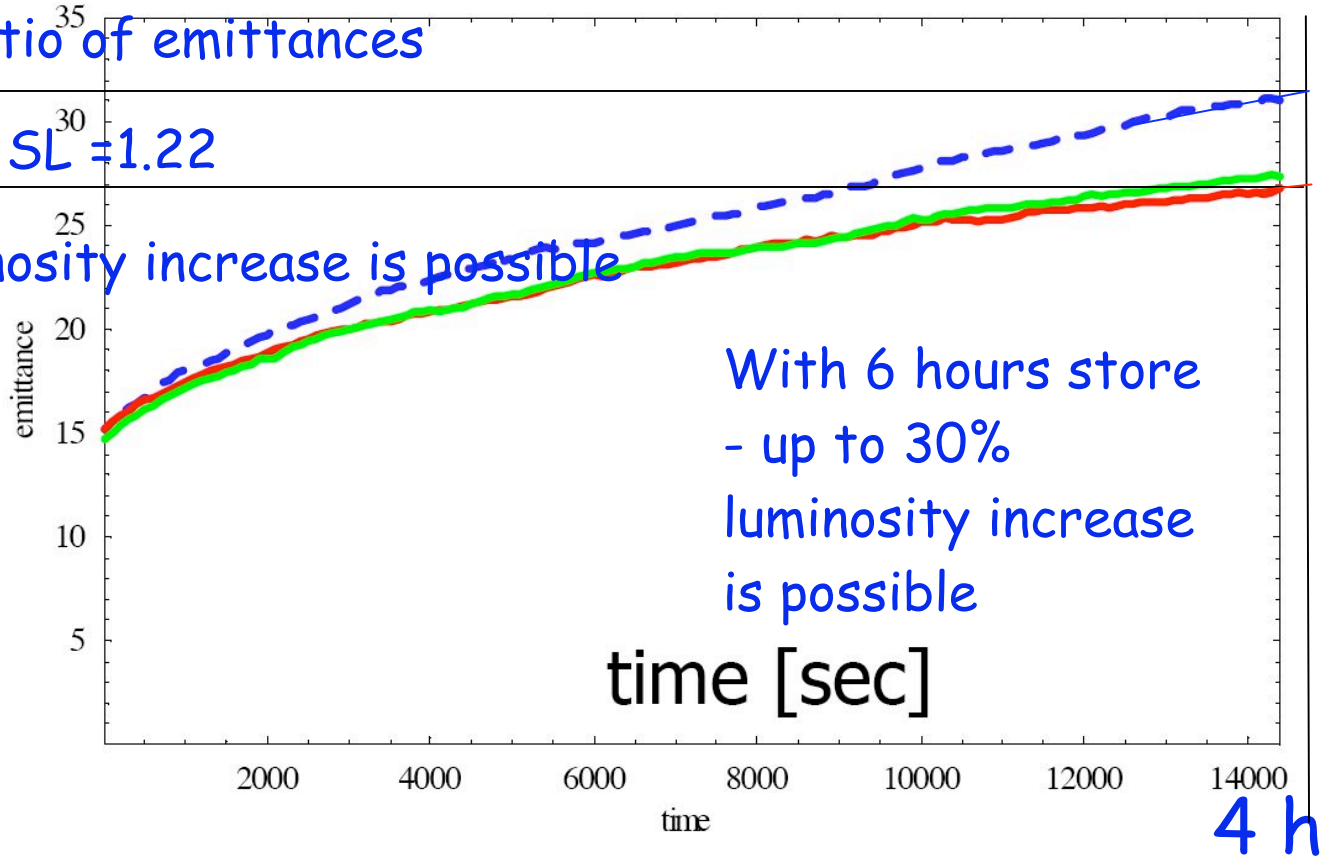
Main advantage comes from beta*

95% normalized emittance growth: 1) blue – 82 deg. lattice; 2) red – 92 deg. lattice with dispersion wave; 3) green – 92 deg. lattice without dispersion wave

In 4 hours ratio of emittances

Normal/ IBS SL =1.22

i.e. 22% luminosity increase is possible



With 6 hours store - up to 30% luminosity increase is possible

time [sec]

4 hours

Main advantages

- β^* for IBS lattice can be reduced b by 20-25% from that in the standard lattice (1 m to 0.8 m for D-Au) -> 20-25% increase in luminosity
- IBS suppression lattice is natural match for lower β^* and is a good candidate for β^*=0.5m
- 13% RF bucket acceptance increase because of higher γ_t by 13%, i.e. center bunch intensity will be 13% larger for IBS lattice, thus 13% increase in the vertex luminosity (for D-Au - in the case of Au-Au it would be 28%)

Other advantages

- Additional increase in integrated luminosity because of increased life time: +14% (new lumi model) or 5% in Wolfram's model
- 6.5% reduction in bunch length because of larger γ_t - *shorter vertex*
- Overall improvement of luminosity lifetime by 30% - longer stores, less pressure, lower failure rates, fewer ramps….
- Possible reduction on the beam intensity limit at transition because of higher γ_t

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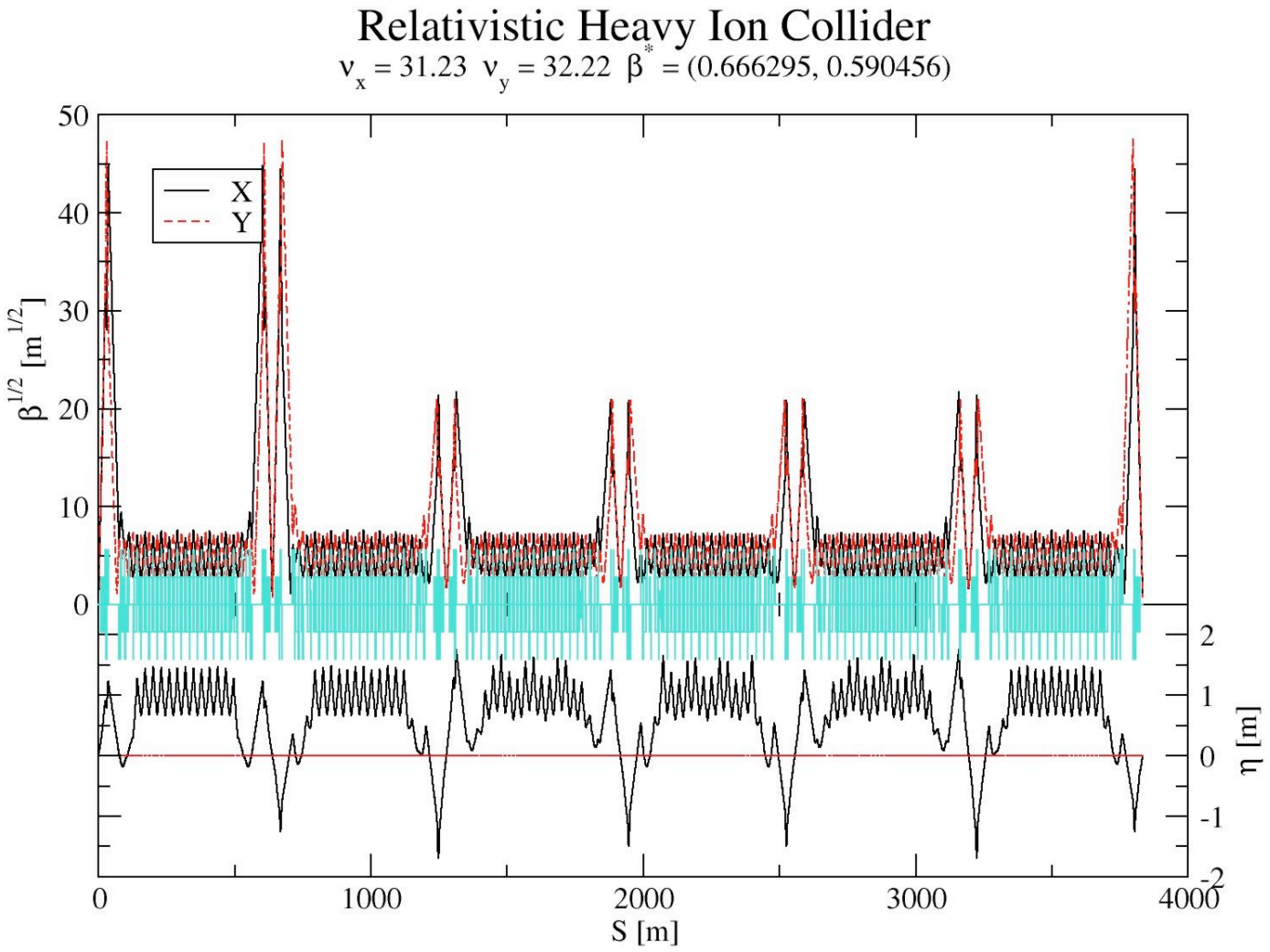
Au lattice for Run 8: β*-> 0.6 m



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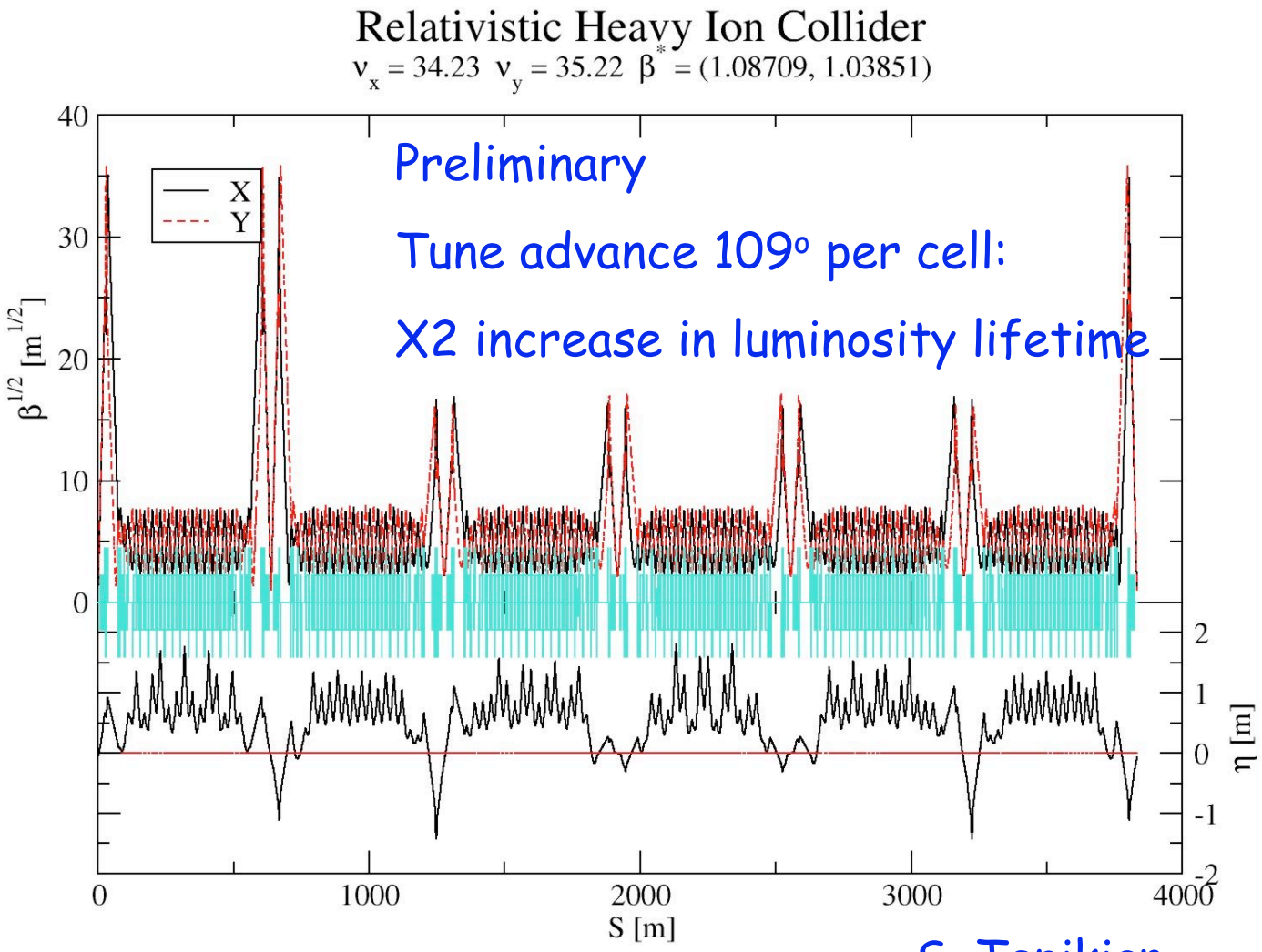
IBS SL with higher tunes



Preliminary

Tune advance 109° per cell:

X2 increase in luminosity lifetime

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Hardware Limitations

- Power supplies, leads and quenching
- Current distribution limitations - H & V strings, the tree of shunting PS - Polarity of trim power supplies
- Sextupole strength
- Growth of γ_t and strength of γ_t quads
- Matching with desirable β^*
- Dynamic aperture (?)
- Effects on coupling compensations scheme, diagnostics using specific tune advances, etc….

Conclusions

- Already developed lattice (92°) has 30% decrease in IBS growth and we expect significant increase in integrated & vertex luminosity
- APEX:
  - Examine possibility of further increase in the phase advance with present hardware
  - Try to push β^*-> 0.5 m with the IBS suppression lattice
- New territory for RHIC
- Need to find a way of making PS chain more flexible (SCR polarity switchers for uni-polar PS, etc..)
- Study effect of higher current in main quad power supplies on the reliability of RHIC
- What is ultimate phase advance 120°? 130°?

Thank you!